10/049220
JC13 Rec'd PCT/PTO 17 JAN 2002

i/prts

Device for Atomizing and Comminuting Liquid Melts

The invention relates to a device for atomizing and comminuting liquid melts, including a slag tundish to whose outlet an expansion or cooling chamber is connected, whereby a propellant gas lance opens into the outlet, which propellant gas lance is surrounded by a tubular underflow weir immersed in the liquid slag.

Devices of the initially defined kind may be used to atomize and granulate slags, whereby a droplet size as small as possible is to be realized in order to cause the rapid cooling and hence vitrification of the slag and, at the same time, obtain a solidified material at a fineness which renders subsequent grinding superfluous. This holds, in particular, with the comminution and vitrification of slag melts which, on account of their latent hydraulic properties, may subsequently be used as cement substitutes or additives to cement mixtures. The tubular underflow weir immersed in the liquid melt may be arranged so as to be adjustable in height in order to obtain a predetermined layer thickness in the region of the outlet, wherein the propellant gas lance itself may, furthermore, be mounted in a height-adjustable manner so as to enable the adjustment of the respectivley optimum positioning in view of the ejection of the liquid melt in the form of a propellant gas jet jacket.

Departing from such an arrangement and a device of that type, the invention aims to provide a construction by which the desired particle size can be substantially reduced, while, at the same time, improving the homogeneity of the grain sizes. The invention, in particular, aims to improve the flow conditions in the outlet region with a view to avoiding fluttering of the film, splashing or an instable behavior of the melt and inducing additional shearing forces in the slag droplets to further enhance comminution. To solve this object, the device according to the invention essentially consists in that the width of the gap between the lower edge of the underflow weir and the tundish bottom is smaller than 20%,

preferably smaller than 15%, of the clear width of the outlet, that the bottom of the tundish in the region between the lower edge of the overflow weir and the outlet is designed in a funnel-shaped manner, and that the propellant gas lance is configured for the use of supercritical vapor to form an underexpanded free jet in the interior of the melt jet. Thereby, conditions are created which enable the injection of supercritical vapor through the propellant gas lance to form an underexpanded free jet in the interior of the melt jet, whereby particularly critical flow conditions are created and the propellant gas stream is caused to emerge at a velocity substantially equalling sonic speed. Taking into consideration the use of supercritical vapor and the fact that, as a result, an underexpanded jet is ejected, pressure impacts in the range of Mach's nodes will subsequently occur with expansion volumina lying between such Mach's nodes. Due to vibration interferences in the two-phase jet, shearing stresses are introduced into the slag droplets, whereby the frequency is accordingly increased at increasingly supercritical conditions, thus accordingly reducing the distance between Mach's nodes in the axial direction of the propellant gas jet. The fact that an underexpanded jet is ejected at supercritical conditions results in an expansion immediately upon emergence from the nozzle with the speed at the mouth of the nozzle corresponding exactly to sonic speed, if the pre-pressure in the nozzle is at least supercritically higher than the pressure prevailing immediately upon emergence from the nozzle. By choosing the width of the gap between the lower edge of the underflow weir and the tundish bottom to be smaller than 20% and, preferably, smaller than 15% than the clear width of the outlet, it is ensured that a sufficiently central free space will be obtained within the running-off jet, which enables the appropriate lowering of the propellant gas lance to close to, or into, the outlet opening. This is of importance, particularly because, bearing in mind the special flow conditions brought about by a supercritical vapor or an underexpanded free jet, the melt nozzle is subjected to high mechanical stresses in the region of the outlet of the tundish, unless Mach's vibration nodes occur at a sufficiently

large distance from the outlet mouth. It is, thus, to be safeguarded that no Mach's nodes will occur in the region of the mouth itself in order prevent excessive wear by erosion and cavitation phenomena in the region of the slag or melt outlet. By designing the bottom of the tundish in a funnel-shaped manner in the region between the lower edge of the underflow weir and the outlet, it is ensured that the formation of annular beads as a function of the respective viscosity of the melt will be prevented in order to prevent the separation of the flow shortly after its entry into the bottom outlet and avoid fluttering of the film as well as optionally splashing and an instable behavior of the melt. In the optimum case, the inclination of the funnel is dimensioned such that the layer thickness defined by the distance of the lower edge of the underflow weir from the bottom of the tundish will be largely maintained, or else reduced, as far as to the brink of the outlet.

In accordance with the invention, when keeping supercritical conditions for the vapor within the propellant gas jet and ejecting an underexpanded free jet, it is operated in a manner that the flow speed at the nozzle mouth of the lance exactly corresponds to sonic speed.

In order to reliably prevent the formation of beads in the region of the slag outlet, as indicated above, the configuration advantageously is devised such that the angle of inclination α of the funnel-shaped tundish bottom region is chosen to be smaller than 30°, preferably approximately 20°, relative to the cross sectional plane of the outlet.

In principle, it is of advantage if the tundish and the melt or slag on stock in the tundish are heated, to which end an inductive heating is advantageously provided. In the context of the invention, the configuration in a particularly advantageous manner is devised such that the tundish comprises heating elements to heat with medium-frequency current, and that at least the underflow weir is made of an electrically conductive material such as, e.g., C, SiC or ZrO_2 and

$ZrO_2.MgO$, respectively, whereby, when using a medium-frequency current as opposed to applying high-frequency heating, by which only the external region of the slag tundish becomes appropriately heatable due to the skin effect, it is feasible to heat also the underflow weir if the latter is made of an electrically conductive material. Advantageously, the configuration is devised such that the outlet region of the tundish is made of SiC, Al_2O_3 or ZrO_2 or $ZrO_2.MgO$, respectively, with the tundish preferably being made of graphite or SiC. In this manner, it is feasible, when using a medium-frequency current, to ensure appropriate heating on critical points and use the respective heat transmission onto the melt bath for fine temperature adjustment as well as to melt possibly entrained solids particles.

According to the invention, the configuration advantageously is devised such that the propellant gas lance is designed for a propellant vapor having a temperature of between 600° and 1250°C at a pressure ranging between 2 and 5 bars.

The ejection of an underexpanded free jet necessarily causes such a free jet to exhibit a certain divergence. However, taking into account the supercritical ejection conditions, this divergence is supposed to be extremely low and, strictly speaking, substantially constitutes a free jet having a cylindrical envelope with a relatively low divergence. Such a jet geometry exhibiting a relatively low divergence offers the advantage that the nozzle mouth of the lance can be kept at a larger distance (S) from the outlet opening without the wear in the region of the outlet substantially increasing. Particularly favorable conditions in terms of wear, of a slag outlet optionally designed as a separate charging component in this respect advantageously may be achieved in that the slag outlet of the tundish, following the funnel-shaped inlet, is designed to be hollow-conical or cylindrical over an axial length corresponding to 0.6 to 1.1 times the clear diameter of the outlet opening, the outlet opening advantageously widening conically following the hollow-conical or cylindrical region.

In order to optimize the rheologic properties of slags, in particular of, for instance, typical blast furnace slags, the addition of fluxes such as, e.g., fluorspar (CaF_2) has proved to be extremely advantageous. The dynamic viscosity of a blast furnace slag having a CaO to SiO_2 ratio of about 1 and an Al_2O_3 content of about 9% by weight at 1480°C may, thus, be divided by half through the addition of, for instance, 1.2% by weight of CaF_2, thus both saving the refractory material and increasing droplet comminution. At the same time, an increase in the early strength of mixed cements produced by using such comminuted products has been observed.

In the following, the invention will be explained in more detail by way of an exemplary embodiment of the device according to the invention schematically illustrated in the drawing. Therein, Fig. 1 illustrates a section through the tundish in the region of the slag outlet and Fig. 2 shows an enlarged detailed illustration of a modified slag outlet.

Fig. 1 depicts a propellant-vapor gas lance 1 including an ejection nozzle, which is mounted so as to be adjustable in height in the sense of double arrow 2. The propellant-vapor gas lance is concentrically surrounded by a tubular weir 3 made of an electrically conductive material. This tubular weir 3 likewise is adjustable in height in the sense of double arrow 4, in order to ensure an appropriate distance of the lower edge of the tubular underflow weir relative to the bottom 5 of a tundish 6. The tundish 6 is closeable by a lid 7 and comprises an outlet 8 whose surfaces facing the melt 9 are designed in a funnel-shaped manner. The angle of inclination α substantially amounts to 20° so as to ensure a laminar flow of the slag in the outlet region at a given slag viscosity. The slag outlet 8 is designed as a separate charging component, widening in a funnel-shaped manner on its external side 10 facing away from the slag chamber, whereby the angle of conicity β of this funnel-shaped enlargement is chosen to be larger than, or equal to, the angle of divergence γ of the free jet 11, which is illustrated in the drawing in an exaggerated manner. The propellant gas or propellant vapor -

gas mixture leaves the lance 1 in a manner so as to form underexpanded jet, which results in the formation of Mach's vibration nodes 12 between expansion volumes 13. After its emergence from the lance 1, the free jet collides with the liquid slag jacket, thus causing induced shearing strains and hence further droplet comminution.

The slag tundish is heated with a medium-frequency current, the power source being denoted by 14 and the pertinent coil being denoted by 15. The coil itself may be heated by the aid of cooling water, which is supplied through duct 16, so that heated cooling water may be drawn off through connection 17. Since inductive heating is realized by means of medium-frequency current, skin effects are avoided and it is feasible to heat also the tubular underflow weir 3, if the latter is made of an electrically conductive material such as, for instance, carbon, silicon carbide or zirconium. In the latter case, it is to be taken into account that zirconium exhibits the required electric conductivity likewise at temperatures of above 800°C.

When using a propellant vapor at a lance pressure of approximately 2.5 bars and a temperature of approximately 800°C, and hence supercritical conditions, rapid expansion and hence rapid cooling to temperatures in the range of 650°C are caused immediately upon emergence from the lance at a flow velocity corresponding to sonic speed. If a propellant vapor is used at a temperature of 600°C and a pressure of approximately 2.5 bars, the temperature will decrease to about 475°C, whereby an ejection at sonic speed and, thus, the creation of shearing forces suitable to effectively comminute the slag droplets will be achieved also in this case.

Fig. 2 depicts the slag outlet 8 on an enlarged scale. As already mentioned, the angle of divergence γ represented in Fig. 1 does not correspond to the actual conditions prevailing at a supercritical and underexpanded jet, whose envelope has nearly a cylindrical shape. As is apparent from Fig. 2, a substantially hollow-cylindrical region is provided to follow

the funnel-shaped configuration while enclosing an angle of inclination α, the axial length L of said hollow-cylindrical region substantially corresponding to the diameter D of the clear width of the outlet opening. Following this substantially hollow-cylindrical region, the slag outlet opening again widens in a funnel-like manner as indicated by the conical walls 10.